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Evaluation of the influence of aircraft landing lights on flight behavior of migrating birds at night has been completed. Birds do not make evasive maneuvers to avoid approaching aircrafts with their landing lights on. Evaluation of the AN/TVS-5 image intensifier shows that it is an ideal instrument to use in quantifying and monitoring bird migrations. The correlation between migration traffic rate and the density of bird echoes on the radar screen is identical on different nights when the magnitude of migration is the same. An automatic system composed of an image intensifier in combination with a closed circuit television video tape system has been developed to gather more accurate data on nocturnal migration.

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RADAR TECHNIQUES FOR AIR FORCE APPLICATIONS IN AVOIDANCE OF BIRD-AIRCRAFT COLLISIONS AND IMPROVEMENT OF FLIGHT SAFETY FINAL TECHNICAL REPORT

AFOSR GRANT 75-2782

Principal Investigator: Sidney A. Gauthreaux, Jr., Department of Zoology, Clemson University, Clemson, SC 29631

1 February 1979

INTRODUCTION

In this final technical report I review the major accomplishments of AFOSR Grant 75-2782 that covered the period from 1 December 1974 to 30 December 1978. Because much of the information concerning this period has been reviewed in previous interim and progress reports (1 Decmeber 1975, 1 February 1977, 1 August 1977, 10 August 1978), I will concentrate on the period 1 January-30 December 1978. During this year several achievements were realized in my research program. An evaluation of the influence of aircraft landing lights on the flight behavior of migrating birds at night was completed. The use of the AN/TVS-5 second generation image intensifier as a device to detect and monitor nocturnal bird migration aloft was examined, and the feasibility of quantifying the displays of bird migration on the ASR-5 radar with the use of moon-watching or the ceilometer-image intensifier technique was investigated. The development of an image intensifier-closed circuit television (I^2CCTV) system to detect and quantify nocturnal bird migration aloft was completed, and studies on the daytime migration of birds using the ASR-5 radar at the Greenville-Spartanburg Airport were initiated in September. In addition, the principal investigator attended the XIIIth Meeting of Bird Strike Committee Europe in Bern, Switzerland, and the XVIIth International Ornithological Congress in West Berlin, Germany during the summer. Finally, a number of papers were published during the year that acknowledge either direct or indirect support from AFOSR grant 75-2782.

RESEARCH

Aircraft Landing Lights

Although there has been considerable inquiry about the use of aircraft landing lights to "clear a path free of birds for the aircraft at night," and several pleas made for more research on the effects of aircraft landing lights on the flight behavior of migrating birds at night, virtually no work has been done on this important subject. Since the spring of 1977, I have used the ASR-5 radar on short range (6 nautical miles) to see if the flight behavior of birds changed when the birds were illuminated by the landing lights of jet aircraft landing at or taking off from the Greenville-Spartanburg Jetport in South Carolina. By carefully observing the echoes from migrating birds ahead of the echo from the aircraft with its landing lights burning, it was possible to see if the birds responded to the approaching lights and aircraft. In each case the tower personnel informed me when the aircraft's landing lights were turned on during landing or turned off after takeoff. Polaroids and 16-mm movies were occasionally made during these periods to document the spatial pattern of the bird echoes.

On the basis of 120 instances when aircraft were landing or taking off I found no case when the bird echoes showed movement patterns that suggested evasive action. The spatial distribution of the echoes showed no change before or after the passage of the aircraft. On approximately 30 occasions the pilot of the aircraft reported to the tower that many birds were visible in the landing lights of the aircraft, and on two nights when bird migration was unusually dense (approximately 200,000 to 300,000 birds crossing a mile of front per hour), all aircraft landing at the airport (a total of eight) experienced several impacts from small birds. A pilot commented on one of these occasions that the number of birds observed in the aircraft's landing lights was so great that they appeared like moths. Thus all available evidence indicates that migrating birds do not make evasive movements in response to the approaching landing lights of an aircraft. This finding is in contrast to that reported by Larkin et al. (1975). Unfortunately

my data cannot clarify whether or not the aircraft landing lights are somewhat of an attraction to the nocturnal migrants. This type of response has been noted on many occasions when migrating birds at night have been attracted to lighthouses, lighted buildings, and lighted windows, and it would not be surprising to find a similar response to aircraft landing lights. This will require additional work at some future date.

Image Intensifier Research

In the spring of 1975 I obtained on loan from the Night Vision Laboratory at Fort Belvoir, Virginia, a seven power (7X) image intensifier (AN/TVS-2) to investigate a new method of studying the movements of birds aloft at night. This technique is clearly a breakthrough in the study of nocturnal bird migration. In the spring of 1977 I obtained on loan a newer model image intensifier (AN/TVS-5), and during the spring and fall of 1977 and the spring of 1978, I completed work on the feasibility of using this new instrument to detect and monitor the nocturnal migration of birds aloft. This new second generation image intensifier has greater resolution, higher gain, less spherical aberration, and is smaller in size and weighs less than the older AN/TVS-2 that I used previously.

A total of 85 hours has been spent viewing nocturnal migration with the AN/TVS-5 at the Greenville-Spartanburg Jetport and near Clemson, South Carolina. The image intensifier is usually directed vertically up a beam of light produced by a PAR-64 300-watt very narrow spot light, but it can also be used at night in areas with considerable ground lighting (e.g., a city). All data collected by this technique have been analyzed, and some have been presented at scientific meetings (see Gauthreaux 1978--The importance of daytime flights of nocturnal migrants: Redetermined migration following displacement, In Proc. Symp. Animal Migration, Navigation

and Homing [K. Schmid-Koenig and W. Keeton, eds.] Springer-Verlag, New York, pp. 219-227).

The use of image intensification to study nocturnal bird migration represents a new and frankly exciting breakthrough. The technique is very easy to use and can detect and monitor bird movements even at altitudes of 2,000 meters. Moreover, various types of birds can be identified when they fly through the field of view. I have been able to observe easily small individual songbirds, flocks of shorebirds, flocks of ducks, and herons migrating high in the night sky. The results indicate that electro-optical devices such as an image intensifier can be successfully used to study the nocturnal movements of birds. The data gathered with the AN/TVS-5 are now being statistically analyzed along with the considerable weather data collected at the same time in an effort to refine the multivariate predictive models of intense bird migrations (see Gauthreaux 1978---"The influence of weather variables on the density of nocturnal migration in spring" Proc. XIIth Meeting Bird Strike Committee Europe, Paris). The data gathered with the AN/TVS-5 is also being used to quantify the displays of nocturnal migration on the ASR-5 radar. Because the dimensions of the sampling volume of the AN/TVS-5 are fixed, it is a straightforward calculation to compute the number of birds observed per hour, provided wind speeds are the same on each occasion. The results of such computations yield migration traffic rates, the number of birds crossing a mile of front per hour. The quantitative results can then be used to quantify photographs of the displays of bird echoes on the radar screen that have been taken simultaneously. (see Gauthreaux 1978--- The quantification of bird migration densities with surveillance radars. In: Proc. IIIrd World Conference on Bird Hazards to Aircraft, Paris, France, October 19-28, 1977. ICAO Pub. #E4/163-78/40). The most recent developments involving the use of image intensification are discussed in the section of this report dealing with the image intensification-closed circuit television (I^2CCTV) system.

Quantification of Bird Migration Displayed on ASR-5 Radar

At both the XIIth and XIIIth meetings of Bird Strike Committee Europe in Paris, France and Bern, Switzerland, respectively, there was general agreement that the displays of bird echoes on surveillance radars needed to be more accurately quantified so that hazardous conditions could be determined quantitatively instead of qualitatively. I have devoted considerable attention to this problem over the last several years, (Gauthreaux 1970) but only recently have I been able to develop a method of quantifying the displays of migrating birds on airport surveillance radars (ASR series of radars operated by the Federal Aviation Administration).

Because the controls of the ASR radars throughout the United States have been modified so that the IF gain is fixed at a maximum, and the sensitivity time control (STC) circuits are fixed at discrete levels of attenuation, it is now possible to quantify the displays of bird migration on the plan position indicator (PPI) so that the results can be used at other ASR-5 radars with the same settings. I have been doing this research for the last year, and the results are encouraging (see Gauthreaux 1978---"The quantification of bird migration using surveillance radars" Proc. IIIrd World Conf. Bird Hazards to Aircraft, Paris, ICAO Report). The most important finding at this stage of the research is that the results can be replicated, that is when migrations on two different nights are of the same magnitude, the photographs of the radar displays of migration show identical densities of echoes. This phase of the research has been completed and the resulting series of photographs shows a full range of echo densities with accompanying migration traffic rates. A paper describing the technique and results is nearing completion and will be submitted to a journal within a month. The information should prove quite useful to air traffic controllers and enable them to measure the amount of migration displayed on their radar scopes. The current use of the 0-8 density scale to measure the amount of migration displayed on the radar PPI (see ICAO Airport Services Manual, 1975, Part 3, pp. 43-44) is clearly inadequate, and a series of photographs that has accurate measures of migration traffic rates will prove to be far superior. Quantified

radar displays will also facilitate computation of bird strike probabilities.

Image Intensifier-Closed Circuit Television (I^2CCTV) System

During the spring of 1978 the AN/TVS-5 image intensifier was coupled with a low light level television camera (HV-17LU CCTV) in an attempt to develop a system that could monitor nocturnal bird migration aloft and permit more detailed analysis of various aspects of the migration (e.g., quantity of birds, type of migrants, altitudinal distribution, orientation). By connecting the image intensifier-closed circuit television camera to a video monitor and video tape deck, analysis can be made directly from the monitor on location or made later from the video tape record at a time and location convenient to the investigator. Thus with the automated system it is now possible to detect, quantify, and monitor nocturnal bird migration throughout the night either "live" by viewing the TV monitor or by "playback" with the aid of the video tape recorder. Intensive use of the system during the fall of 1978 has resulted in considerable data that are currently being evaluated and analyzed. Although data analysis is not yet completed it can be said that the system is one of the most improtant developments in my research since I began using radar. The I^2CCTV system works exceptionally well and provides detailed information on the migration of birds at night.

The future application of the I^2CCTV system will certainly lessen the hazards that nocturnally migrating birds pose to aircraft and their pilots. The system can be used to warn air traffic controllers of hazardous concentrations of migrating birds aloft at night with rather simple modifications. The modifications could produce an audible signal when migration reaches hazardous densities, or similarly, a series of differently colored lights each indicating a different density of migration. Of course ATC personnel could

view the video monitor directly and note the frequency with which birds cross the field of view on the TV screen. Ultimately the I^2CCTV system could be incorporated with other avionics in the cockpit, and when used in conjunction with the aircraft's landing lights at night, the pilot could detect hazardous concentrations of birds at great distances.

Daytime Migration Studies

Considerable emphasis on nocturnal bird migration in the United States has resulted in abundant data on the subject, but relatively little is known about daytime migration. Based on extensive data from Europe, and some data from the U.S., daytime movements should constitute a great hazard to aviation becuase most birds migrate in flocks during the daylight hours. In an effort to examine the quantity of daytime migration and its interrelationship with weather conditions, a radar and direct visual study of daytime bird migration in northwestern South Carolina was initiated in the fall of 1978. The study will continue through the spring of 1979. Thus far 23 mornings between 26 September and 19 October 1978 have been sampled. The ASR-5 radar at the Greenville-Spartanburg Jetport is being used during the morning hours from 07:30 until 09:30 EST to monitor the movements and photographs of the displays of bird movements are taken at least twice during this period. Meteorological data are also recorded in the radar room (e.g., barometric pressure, wind direction and speed, percent cloud cover, cloud cover type, visibility, and temperature). Once the study is completed the weather data and migration data will be analyzed using multivariate statistical procedures in an attempt to generate a predictive model of dense daytime flights. To identify the sources of the bird echoes displayed on the radar screen, direct visual watches with 8 X and 10 X binoculars are made outside the radar station immediately after photographs of the radar screen are taken. In this manner it is

possible to verify the information taken from the radar displays. During direct visual watches the type of birds observed, their numbers, flight formations, height and directions of flight are recorded. In most cases direction is not recorded until the birds have traveled far enough away to note a disappearing azimuth. This, then, enables one to compare, almost simultaneously, data from the radar screen and from direct observation with binoculars. This technique also helps to detect both high migrants (via radar) unable to be seen with binoculars and low migrants that might not appear on the radar screen because of ground clutter.

International Meetings Attended

In June of this year I participated in the XIIIth Meeting of Bird Strike Committee Europe in Bern, Switzerland, and then attended the XVIIth International Ornithological Congress in West Berlin, where I presented a paper as part of a symposium on World Patterns of Bird Migration which I co-organized with Dr. Gerhardt Zink of West Germany.

Special Lectures

In January of this year I presented an invited paper on the patterns of bird migration to a group assembled at Oak Ridge, Tennessee, to examine the impact of transmission lines on migrating birds. The electric power industry is greatly concerned with this problem, and they believe that some of the work done on the bird/aircraft collision problem may be of significant assistance to them, particularly the radar and direct visual techniques of monitoring bird movements.

INVITED PAPERS PRESENTED
(AFOSR support acknowledged)

1. "Migratory behavior and flight patterns." Workshop on Impact of Transmission Lines on Migratory Birds, Oak Ridge, Tennessee, January 1978.
2. "The influence of global climatological factors on the evolution of bird migratory pathways." XVIIth International Ornithological Congress, West Berlin, Germany, June 1978.

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